CLEAR ALIGNER TREATMENT

Graber 6th edition

INTRODUCTI ON

- ***Invisalign is an orthodontic technique that uses a series of computer-generated custom plastic aligners to guide the teeth gradually into proper alignment.*** (It has been commercially available to orthodontists since 1998.)

- In 1945, ***Dr. Harold Dean Kesling*** first proposed a clear, vacuum-formed tooth-positioning appliance for minor tooth movement – 'POSITIONER'
- It was a labor-intensive process that required manually repositioning teeth reset in wax,

John J Sheridan and colleagues (1993) developed a technique involving interproximal tooth reduction and progressive alignment using *clear Essix appliances*

- And those techniques were further developed by ***Hilliard Jack K*** and ***John J Sheridan*** (2000) with a series of special thermoforming pliers designed to enhance specific movements.
- Although these techniques based on Kesling's proposal of using removable appliances have been used to some degree in the past, the laboratory construction has always been tedious and has previously limited the widespread adoption of removable aligner

Clear aligners can be categorized into four basic categories:

1. Positioners or guides:

- This category includes positioner described by Kesling.

2. Thermoformed appliances:

- Sometimes known as Essix Retainers and removable appliances referred to as spring aligners.
- The Essix appliance can be fabricated in the orthodontist's office or sent to a commercial laboratory, and it uses the techniques of Sheridan and Hilliard to move teeth.

3. Teeth manually set:

- Aligners that are fabricated from models that have had teeth cut out and manually moved to the correct position.
- If done in a series of models, an aligner can be fabricated from each model.
- These appliances can be used for minor movement of upper and lower anterior teeth and usually consist of three to five aligners.

4. aligners fabricated from digitally manipulated models

- Is the largest growing area in aligner treatment.
- This growth is most likely attributable to the ability of these aligners to be used to treat malocclusions

INDICATIONS OF INVISALIGN

- mildly malaligned malocclusions (1 to 5 mm of crowding or spacing)(With arch expansion or interproximal reduction (IPR)
- deep overbite problems (e.g., Class II division 2) when the overbite can be reduced by intrusion or advancement of incisors
- nonskeletally constricted arches that can be expanded with limited tipping of the teeth.
- Lower incisor extraction for severe crowding
- Tip molar distally

Requires Bonded Attachments • Extrusion of incisors • Incisor or canine rotation correction • Translation of molars

Requires Attachments and Modified Aligners • Premolar extraction space closure • Molar relationship correction • Deep bite correction • Open bite correction

• BOX 10.1 Clear Aligner Therapy (CAT) Applicability

CAT Performs Well

- Mild-to-moderate crowding
  - With arch expansion
  - With interproximal reduction (IPR)
- Posterior dental expansion
- Close mild-to-moderate spacing
- Intrusion of incisors (one or two tooth segments)
- Lower incisor extraction for severe crowding
- Tip molar distally

Requires Bonded Attachments

- Extrusion of incisors
- Incisor or canine rotation correction
- Translation of molars

Requires Attachments and Modified Aligners

- Premolar extraction space closure
- Molar relationship correction
- Deep bite correction
- Open bite correction (?)

CAT Does Not Perform Well

- Prolonged treatment in children
- High canines
- Severe rotations (especially rounded teeth)

.5
.5
.5
The triangles can have 3 different colors
• White: IPR to be performed in future stages
• Yellow: IPR to be performed in the current stage
• Gray: IPR that should have been performed in a previous stage

CONTRA-INDICATIONS OF INVISALIGN

- Severe crowding
- centric-relation and centric-occlusion discrepancies
- severely rotated teeth (more than 20 degrees)
- open bites (anterior and posterior) that need to be closed
- severely tipped teeth (more than 45 degrees)
- teeth with short clinical crowns
- arches with multiple missing teeth.

Clear Aligners

1. push on teeth
2. no need to progress through a series of archwires and tooth movements may occur simultaneously in several planes of space
3. buccal occlusion is 1st corrected, for example, when closing extraction spaces or through sequential distalization, and then the anterior teeth are aligned.
4. limit the proclination of teeth
5. extraction site is first closed and then the anterior teeth are simultaneously aligned as they are retracted, thus minimizing any round tripping.
6. certain teeth may be moved while other teeth may be held immobile during certain stages of treatment.
7. are a maximum anchorage appliance.(very poor at slipping anchorage and mesializing posterior teeth.)
8. periodontal health indices were significantly better
9. Nonextraction treatments may take less time and therefore be more efficient (9.5m longer in xtn cases)

Fixed appliances

1. use archwires to generally pull- on teeth
2. three distinct stages based on the sequence of archwires: alignment, leveling and space closure, detailing and finishing
3. teeth are first aligned and then the buccal occlusion corrected
4. teeth tend to procline during initial alignment and the overbite and overjet decrease
5. anterior teeth are first aligned, usually with proclination, and then subsequently retracted as the extraction spaces are closed.
6. all the teeth are connected to one force system through an archwire(tooth movement in one part of the arch has a reciprocal effect on other teeth in the arch)
7. are a minimum anchorage appliance
8. more efficient in premolar extraction cases

- The strength of clear aligners in managing anchorage, incisor inclination, and vertical control leads to new treatment planning possibilities in which distalization, enamel interproximal reduction (IPR), and expansion may be combined to resolve crowding where extractions would have been required when using fixed appliances.

TERMINOLOG

- ***'Midcourse correction'*** involves a temporary pause in treatment while a new scan is taken or impressions are made; treatment is then continued once new aligners are fabricated.
- reasons: lack of patient compliance; mid-treatment restorative that rendered the current set of aligners unusable as a result of tooth morphologic structure; lack of one or more teeth tracking with aligners as planned, making the fit of the aligners unacceptable; or a change in the treatment plan.
- Proffit reasons for lack of tracking: not enough wear of the aligners by the patient, insufficient interproximal reduction, insufficient crown height or shape to allow a grip on the tooth or teeth to be moved, wrong type or position of bonded

- '***Refinement***' is similar to midcourse correction in that it generally involves pausing treatment and taking new impressions and ordering a new series of aligners.
- The only difference is that refinement takes place near the end of treatment when one or more teeth are apparently not positioned exactly as desired.
- Refinement can be considered similar to artistic detail bends with fixed appliances.

- ‘***Attachments***’ are small composite additions to the tooth surface that enhance areas of undercut either for retention or to facilitate specific movements.

Attachments may be broadly defined into two categories.

1. Conventional attachments are basically handles that allow the aligner to engage a tooth better, these may be horizontal rectangular or vertical rectangular, they may b plan or bevelled
2. Optimized attachments are automatically placed by some aligner software when certain thresholds of tooth movement are reached. They are of

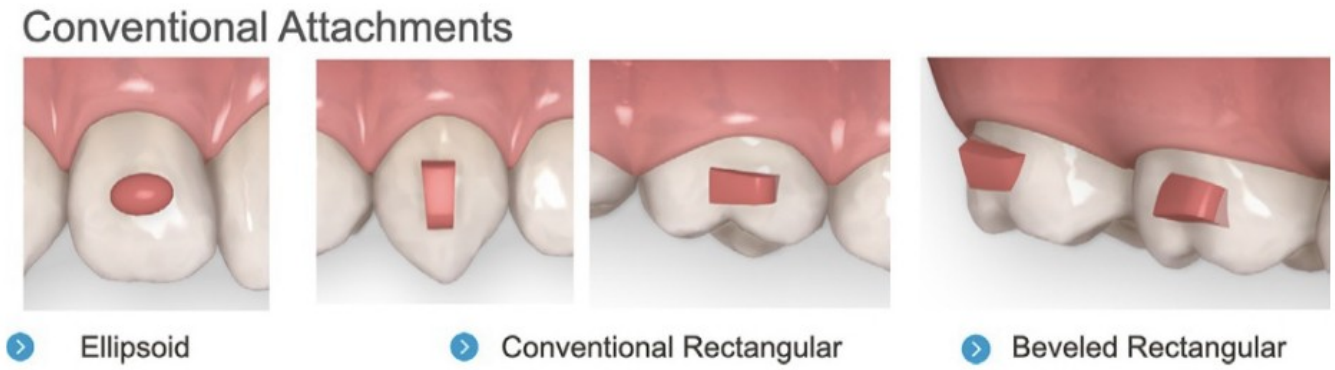


Fig. 22.1 Examples of conventional attachments.

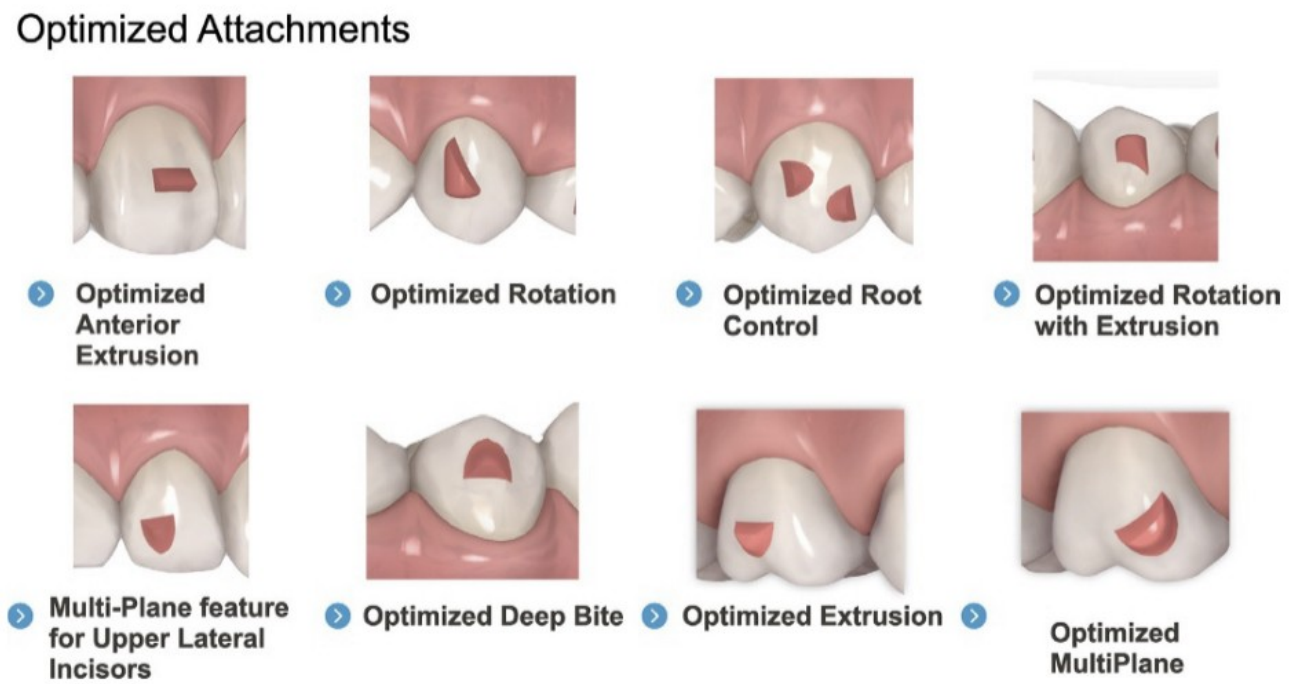


Fig. 22.2 Optimized attachments from Align Technology Inc. for the Invisalign system.

SCANNING AND DIGITIZATION

- An instant virtual model from an intraoral scanner, in combination with multiple software platforms, along with a three-dimensional printer, allows the orthodontist to make aligners easily in his or her office once the cost of the three components (scanner, software, and three- dimensional printer) becomes more affordable.
- Every current scanner has a hand-held wand containing a camera that is connected to a computer for data collection and manipulation.

- The wand may project either laser or white light onto the tooth surface where it is reflected back to the camera, after which hundreds of thousands of measurements per inch are performed to recreate the three-dimensional representation of the teeth.

- All intraoral scanning technologies using a wand have had to deal with cross-arch distortion as the information is stitched together to form a full arch image.

- The scanner manufacturers have managed to correct such dist

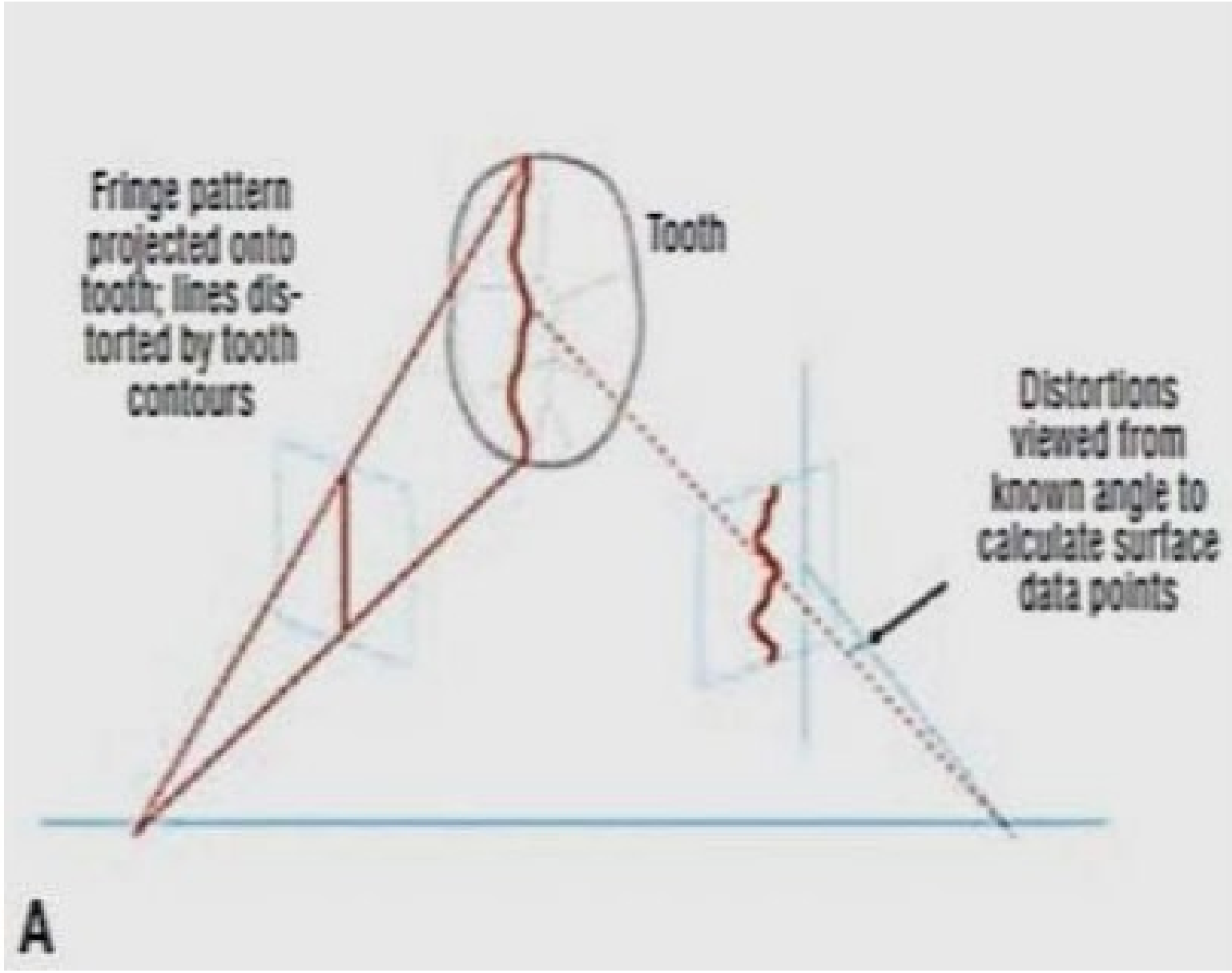
Imaging Technologies

- Four types of imaging technologies are currently used:
  - Triangulation
  - Parallel confocal imaging
  - Accordion fringe interferometry
  - Three-dimensional in-motion video.

- In addition, intraoral ultrasound scanning, although not yet commercially available, is currently in development and should soon be released.

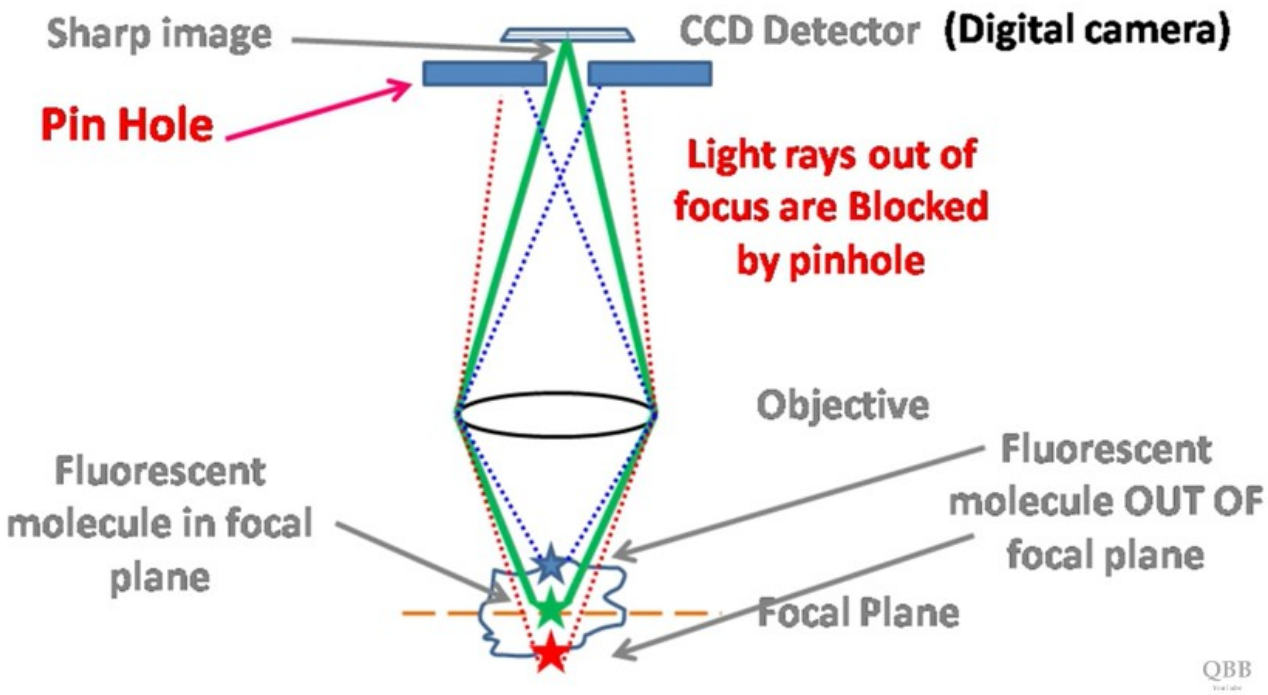
TRIANGULATION

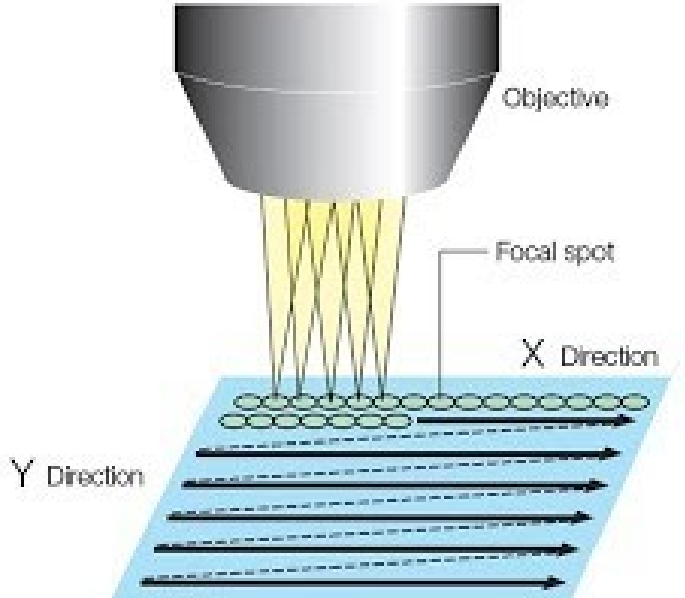
- CEREC (Chairside Economical Restoration of Esthetic Ceramics or CEramic REConstruction) which works using triangulation was the first in-office intraoral scanner
- It was originally developed to scan a crown preparation and then to send the data to a milling machine to create single crowns in the office without the need for impressions.
- This technique uses projected laser light.
- Requires a thin coating of opaque powder to be applied to the target tissue.
- It determines the angle of reflection and the distance from the laser source to the object's surface as light reflects off the object.


Fringe pattern projected onto tooth; lines distorted by tooth contours
Tooth
Distortions viewed from known angle to calculate surface data points
A

PARALLEL CONFOCAL IMAGING

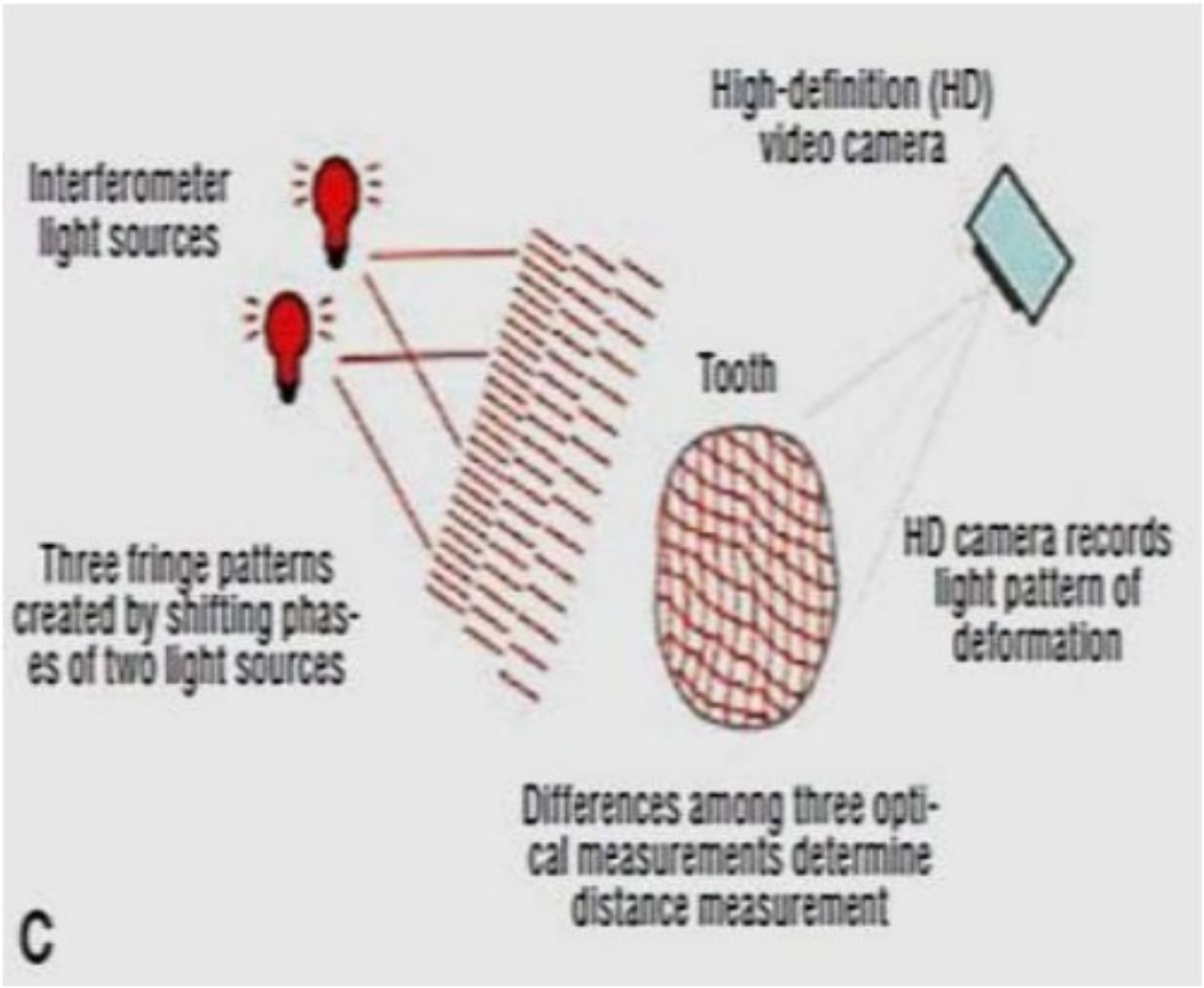
- Projects laser light through a pinhole to the target.
- The sensor is placed at the imaging plane where it is in focus (confocal).
- A small opening in front of the sensor blocks any light from above or below.
- Only the focused light reflecting off the target tissue will reach the sensor for processing.
- This type of system creates thousands of tomographic slices and stitches them together to form the three- dimensional picture.


Sharp image
CCD Detector (Digital camera)
Pin Hole
Light rays out of focus are Blocked by pinhole
Objective
Fluorescent molecule in focal plane
Fluorescent molecule OUT OF focal plane
Focal Plane
QBB


Objective
Focal spot
X Direction
Y Direction

ACCORDION FRINGE INTERFEROMETRY (AFI)

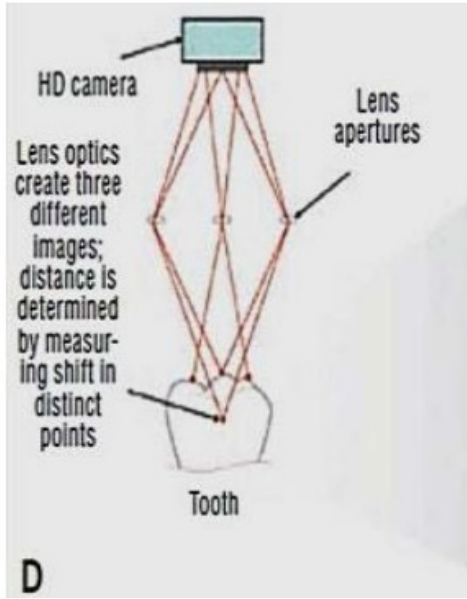
- Two sources of light are used to project three patterns of light, called “fringe patterns,” onto the teeth and tissue.
- Based on the shape of the object, the fringe pattern distorts and takes on a new pattern.
- Surface data points of the fringe curvature are recorded by a high-definition video camera that is offset from the projector by approximately 30 degrees.
- Because the differences among the three precision optical measurements determine the distance measurement, the differential measurement is unaffected by changes in tooth colors and materials.


High-definition (HD) video camera
Interferometer light sources
Tooth
Three fringe patterns created by shifting phases of two light sources
HD camera records light pattern of deformation
Differences among three optical measurements determine distance measurement
C

1
2
3

THREE-DIMENSIONAL, IN-MOTION VIDEO

Uses three tiny high-definition video cameras at the lens to capture three precise views of the target.


HD camera
Lens apertures
Lens optics create three different images; distance is determined by measuring shift in distinct points
Tooth
D

- A sensor behind the cameras converts the light energy into electrical signals, which allows the distances between two data points to be calculated simultaneously from two perspectives to create the three-dimensional data.
- The data points are captured in a video sequence and modeled in real time.
- Powdering may be required to capture surface data points, only a light dusting is needed, compared with the thicker coating needed for triangulation.

- The second part of the process is integrating the software to manipulate teeth in preparation for manufacturing aligners.
- The software must accomplish two things.

1. First, it must fill any voids in the scan itself to produce a workable model;
2. Second, it must allow for tooth segregation and three- dimensional manipulation to produce the intended final setup.

the amount of movement per aligner or stage must be determined by either the orthodontist with a three-dimensional digital orthodontic system or be programmed into the software in the form of a proprietary algorithm (Invisalign).

3-D Printers

- models are printed using three-dimensional printers
- All 3D printers build the object in layers.

A. Stereolithography, liquid resin is held in a build tray and cured layer by layer with an ultraviolet laser light that “draws” a cross-section or outline of each layer in a bottom-up sequence until the model is submerged in the resin bath by the thickness of the build layer for each pass of the laser.
(https://www.youtube.com/watch?v=yW4EbCWaJHE)

B. Fused deposit modeling (FDM) lays down layers of material heated just beyond its melting point, and the material immediately hardens as each layer is applied.
(https://www.youtube.com/watch?v=WHO6G67GJbM)

C. Digital light processing (DLP) is based on a chip technology and is commonly used in home theater projectors.

- With DLP printers, the process is similar to SLA modeling; however, an entire layer is cured at once, resulting in faster build times and a smoother surface finish.

D. PolyJet photopolymerization (PPP) printers are similar to inkjet printers, but PPP printers work in three dimensions rather than two.

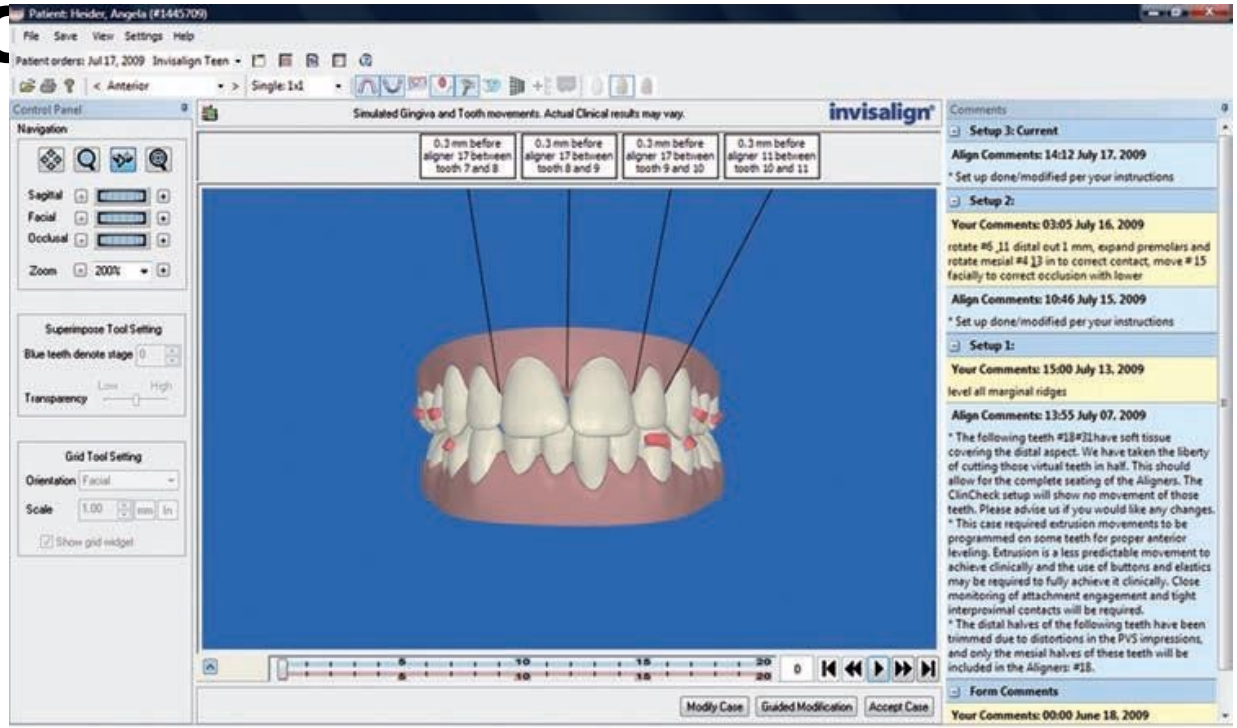
- In PPP printers, the material is sprayed out of nozzles and immediately cured with ultraviolet light.

Four-dimensional printing

- Four-dimensional printing involves using three- dimensional printing and special geometric properties along with material characteristics to print objects that can change their configuration based on outside influences, such as motion or pressure.
- Imagine an aligner that creates its own dimple by increasing the pressure in a specific place on the tooth if the tooth failed to respond as anticipated.

CLINCHECK—AN OVERVIEW

- The virtual setup for Invisalign-branded clear aligner treatment is viewed by the orthodontist in a software program called **ClinC**


Patient: Heider, Angela (#1445709)
File Save View Settings Help
Patient orders: Jul 17, 2009 Invisalign Teen
< Anterior
Single: 1x1
Control Panel
Navigation
Sagittal
Facial
Occlusal
Zoom 200%
Superimpose Tool Setting
Blue teeth denote stage
Transparency
Low High
Grid Tool Setting
Orientation Facial
Scale 1.00 mm in
Show grid widget
Simulated Gingiva and Tooth movements. Actual Clinical results may vary.
invisalign
0.3 mm before aligner 17 between tooth 7 and 8
0.3 mm before aligner 17 between tooth 8 and 9
0.3 mm before aligner 17 between tooth 9 and 10
0.3 mm before aligner 11 between tooth 10 and 11
Modify Case
Guided Modification
Accept Case
Comments
Setup 3: Current
Align Comments: 14:12 July 17, 2009
* Set up done/modified per your instructions
Setup 2:
Your Comments: 03:05 July 16, 2009
rotate #6]1 distal out 1 mm, expand premolars and rotate mesial #4]3 in to correct contact, move # 15 facially to correct occlusion with lower
Align Comments: 10:46 July 15, 2009
* Set up done/modified per your instructions
Setup 1:
Your Comments: 15:00 July 13, 2009
level all marginal ridges
Align Comments: 13:55 July 07, 2009
* The following teeth #18#31have soft tissue covering the distal aspect. We have taken the liberty of cutting those virtual teeth in half. This should allow for the complete seating of the Aligners. The ClinCheck setup will show no movement of those teeth. Please advise us if you would like any changes.
* This case required extrusion movements to be programmed on some teeth for proper anterior leveling. Extrusion is a less predictable movement to achieve clinically and the use of buttons and elastics may be required to fully achieve it clinically. Close monitoring of attachment engagement and tight interproximal contacts will be required.
* The distal halves of the following teeth have been trimmed due to distortions in the PVS impressions, and only the mesial halves of these teeth will be included in the Aligners: #18.
Form Comments
Your Comments: 00:00 June 18, 2009

- **ClinCheck is not the treatment plan, it is the three-dimensional interpretation of the treatment plan by the technician from the prescription form submitted online**.
- **ClinCheck Pro (v4.1)** is the most recent version of the software.

- The technician follows the instructions on the prescription form and delivers tooth movements that fall within the predetermined defaults of Invisalign's Treat software.
- The technician uses a very robust proprietary software called **Treat**, and the orthodontist's interface with that program is a scaled-down version called ClinCheck.
- The single greatest benefit of ClinCheck is its usefulness as a tool for therapeutic diagnosis.

SmartForce

- Once the orthodontist has completed the virtual setup, the true power of the Treat program is exhibited by the application of SmartForce enhancements.
- **SmartForce** features are patented engineered solutions designed to create precise biomechanical forces on selected teeth or groups of teeth.
- These enhancements generally consist of customized computer-designed attachments added to the tooth surface or pressure areas applied to the tooth surface created by altering the digital model before fabricating

SmartForce fea

Optimized Attachments		Name	Introduced
Extrusion	Maxillary centrals, laterals, cuspids		2008
	Mandibular centrals, laterals, cuspids		
	Mandibular bicuspids*	G5	2014
Rotation	Maxillary cuspids, bicuspids		2009
	Mandibular cuspids, bicuspids		
Extrusion/Root and Crown Tip**	Maxillary lateral incisors	Multi-plane	2011
Root Tip**	Maxillary centrals, cuspids, bicuspids	G3	2011
	Mandibular cuspids, bicuspids		

Pressure Points and Areas

Lingual root torque	Maxillary centrals, laterals	Power Ridges	2007
	Mandibular centrals, laterals	Power Ridges	2008
Intrusion	Maxillary centrals, laterals	G5	2014
	Mandibular centrals, laterals, cuspids		

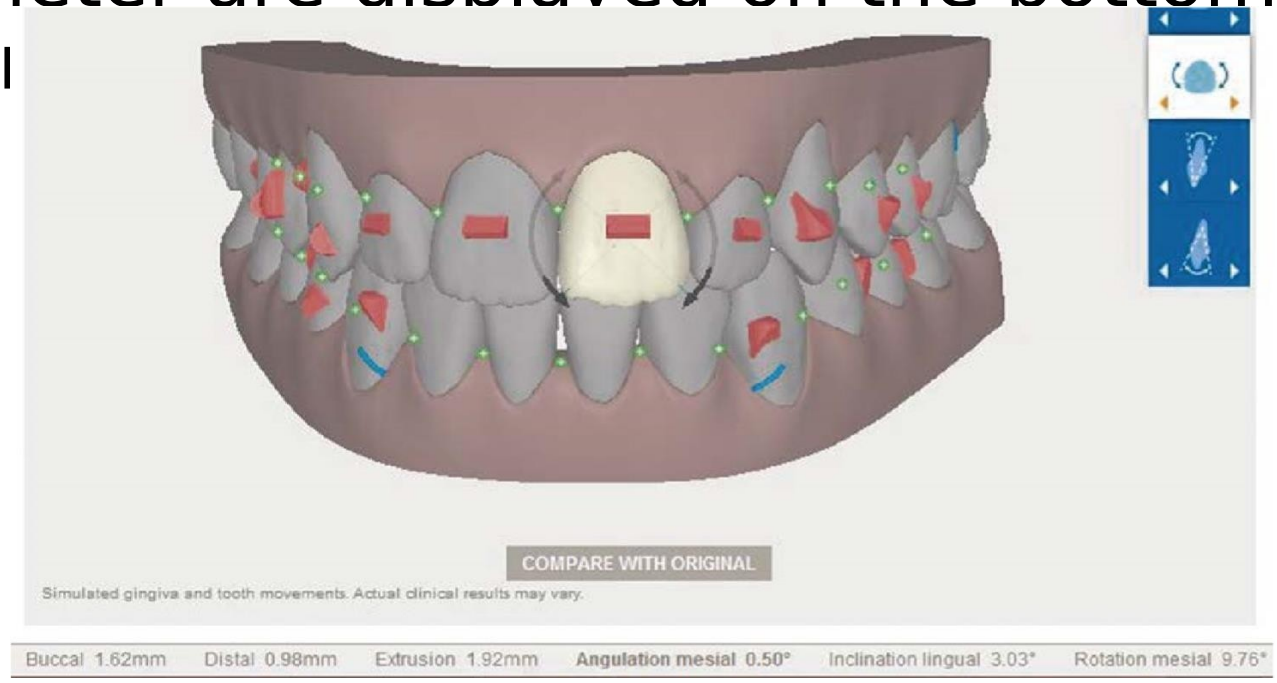
En Masse Features

Anterior open bite closure	Maxillary incisors	G4	2012
Arch leveling: intrusion and extrusion	Maxillary incisors	G5	2014
	Mandibular incisors, cuspids		
	Maxillary bicuspids	G5	2014
	Mandibular bicuspids		
Extraction space closure	Maxillary molars, bicuspids, cuspids	G6	2015
	Mandibular molars, bicuspids, cuspids		

Invisalign generations

- mild crowding (G1)
- relatively complicated tooth movement (G2)
- anterior tooth torque control (G3)
- anterior open bite (G4)
- deep overbite (G5)
- first four premolar extraction, bimax (G6)
- posterior open bite (G7)
- posterior arch expansion (G8)

- With the introduction of ClinCheck Pro (v3.1) and subsequent updates in ClinCheck Pro (v4.1), the value of tooth movement measured to within hundredths of a millimeter are displayed on the bottom of the screen



BIOMECHANICS OF ALIGNER TREATMENT

Control of tooth position and anchorage is often the greatest challenge faced by any orthodontist.

- **Basic design criteria for ortho appliances**

1. not interfere with function
2. cause no harm to the oral tissues or interfere with the maintenance of good oral hygiene
3. should be as light and inconspicuous as possible, yet sufficiently strong to withstand masticatory forces and a reasonable amount of abuse
4. must be firmly retained in position
5. must be capable of exerting an appropriately controlled force in the correct direction and delivering this force for as long as possible between adjustment visits
6. should allow control of anchorage so that tooth

Simple versus Difficult Movements

- With an aligner, the plastic encapsulates the tooth and, must provide both retention and activation to move the teeth.
- In general, the natural undercuts of the teeth provide the retention and the active component to move teeth by the elastic deformation of the aligner, which is important for two reasons:

1. the aligner elastic deformation cannot be as great as to overcome the retention forces
2. certain directions allow the aligner a greater inherent ability to undergo elastic

- Simple movement: For instance, a faciolingual movement is fairly predictable because the entire body of the aligner can be elastically distorted; it then returns to its original shape, carrying the tooth with it.

- The number of aligners or stages, is based on the distance the tooth must be moved.

- Difficult movement: a vertical movement would require the aligner to stretch essentially within the matrix of the plastic and, at the same time, maintain retention of the tooth it is attempting to move.
- these movements must be divided into very small increments and are considered difficult. (difficult movements include controlling torque, root parallelism, rotations, and extrusions)
- multiple movements are considered unpredictable with aligners.

- Aligners are comprised of ***polyurethane***, ***polyester*****, or some combination** or modification of such.
- *Properties of aligner plastic material*:
  - appropriate stiffness to deliver a constant force.
  - high enough formability to enable it to conform precisely to teeth and to any attachments that may exist.
  - highly elastic; when it is stretched, it will return to the shape similar to an arch-wire should, when activated.
  - highly aesthetic and comfortable for the patient to wear.

- The proprietary plastic used to make Invisalign is known as **SmartTrack,** a biocompatible multilayer thermoplastic polymer comprised of *polyurethane and a copolyester*.
- forces as low as 18g are sufficient to produce bodily movement.

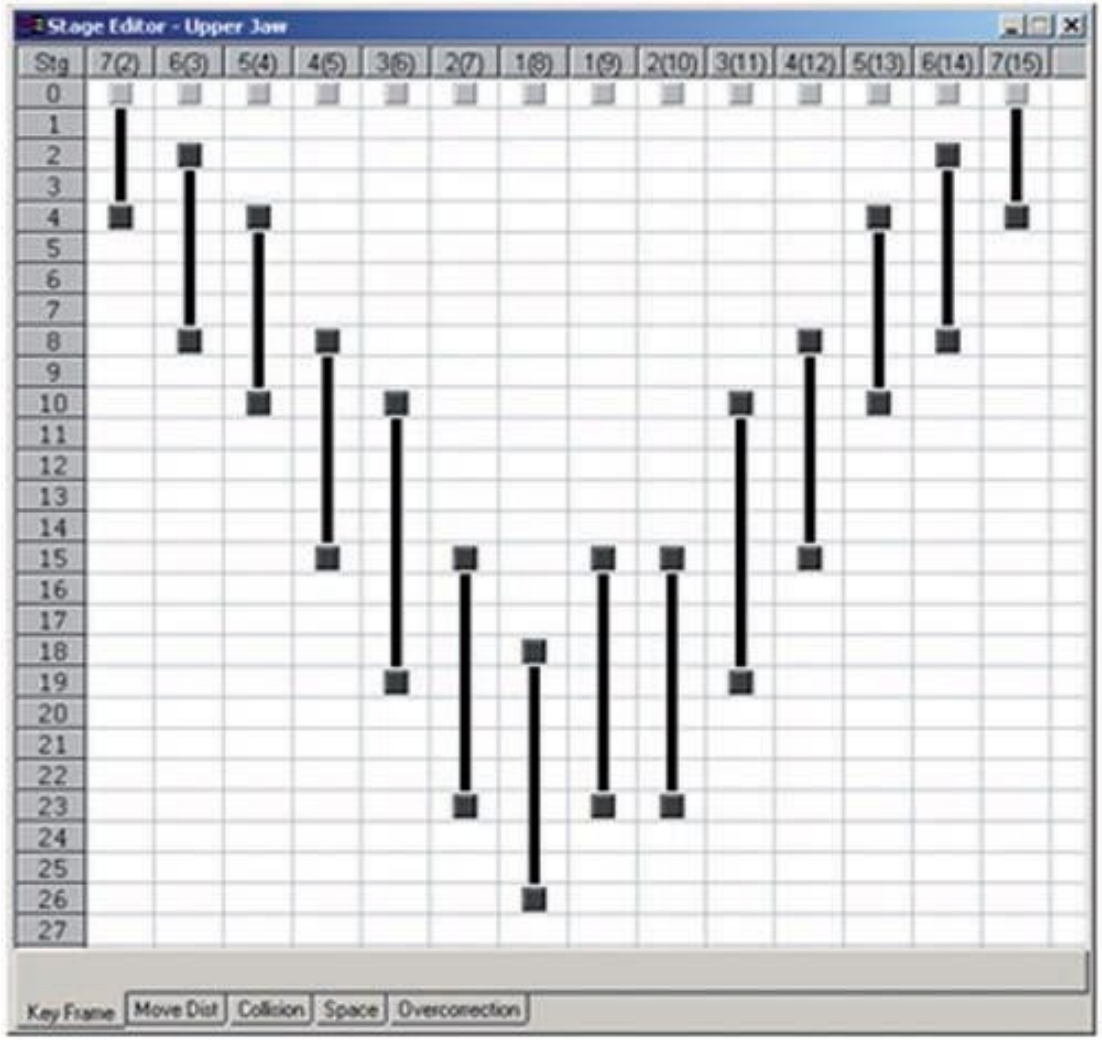
- The goal is to control root position during movement to achieve the desired end results
- Controlling the moment-to-force ratio can do this.

- For effective tooth movement **aligners must be worn 22 hours a day**, essentially the same as for fixed appliances.

- One of the problems that is seen when attempting incisor root movements with aligners is that the intended movement and the actual movement are sometimes different.
- The reason for this difference is exactly what Proffit described as happening with removable appliances in general—**not enough retention is present to offset the force needed to generate the**

STAGI NG

Staging is the sequence in which and speed at which teeth are moved with aligners.

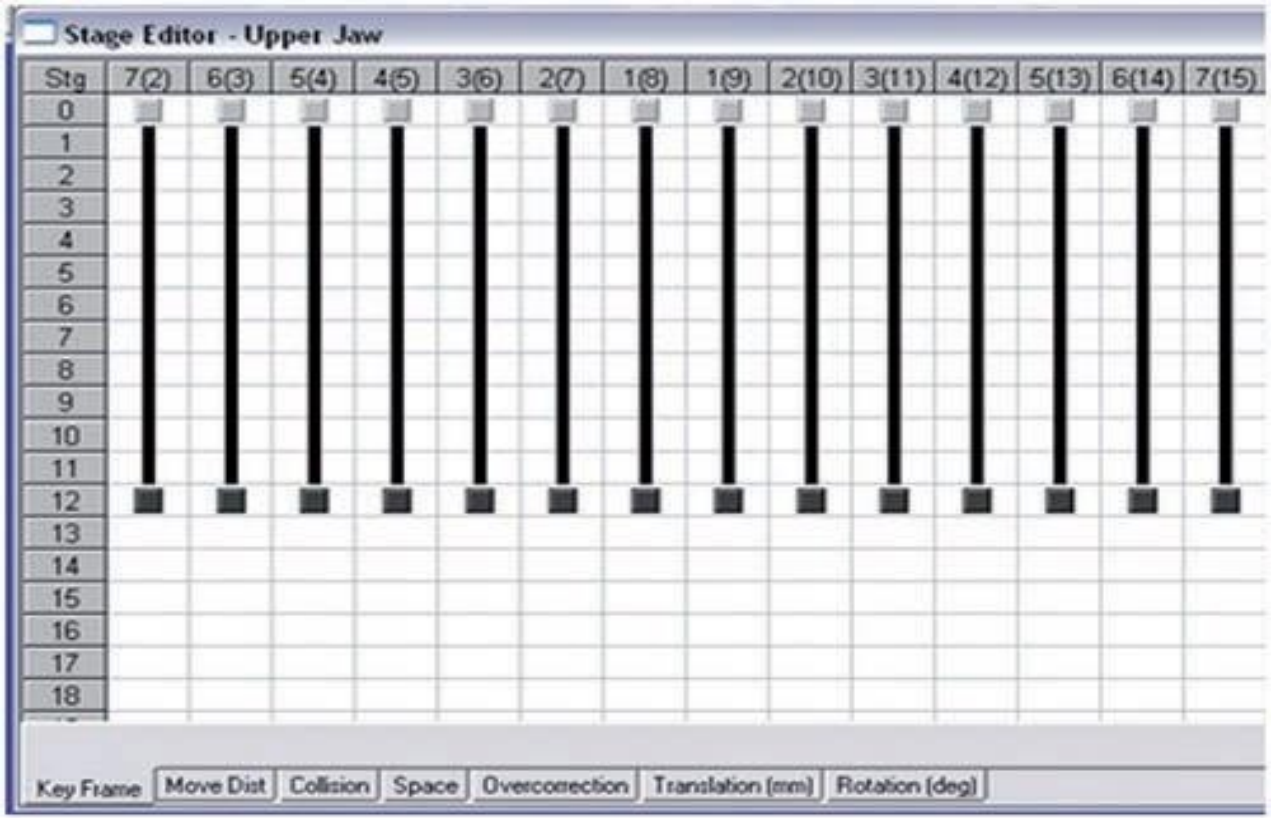


collision table of segmented staging

Collision table:

- The numbers across the top represent different teeth and the vertical axis represents aligner number.
- The vertical black bars in the diagram indicate the timing and rate of tooth movement.
- Each aligner number represents one stage
- **Estimating rate of tooth movement:** dividing the estimated total distance by the number of aligners.

- **X staging:** An alternative to segmented staging that mimics fixed appliance treatment more closely is **simultaneous staging (x-staging).**
- The basis for simultaneous movement is that all the teeth within each arch are moved toge gh the final



- The tooth that moves the most dictates the overall number of stages based on the maximum allowable tooth velocity.
- Moving the other teeth simultaneously from the first to the last stage reduces the velocity for all the other movements and increases their predictability without increasing the overall number of aligners.

- maximum amount of tooth movement allowed per aligner in the Treat software **0.25 mm per stage** and rotational velocity limited to proceed at less than **2 degrees per stage**

Alternative staging patterns:

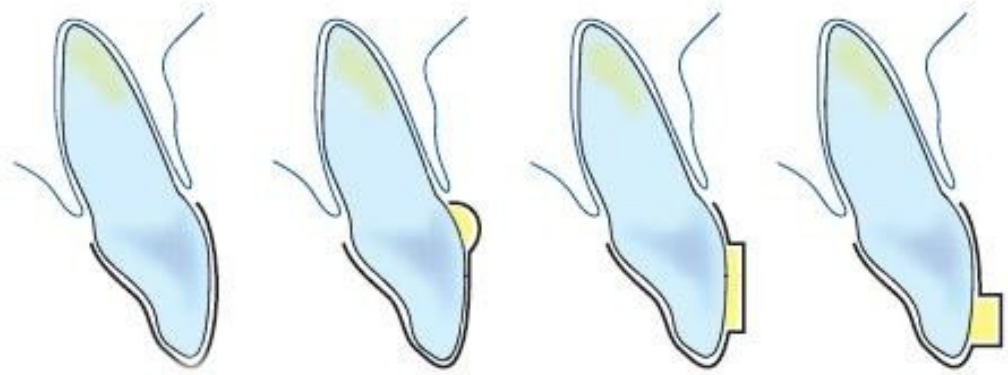
- Distalization of the maxillary dentition, starting with the molars, followed by the bicuspids, and ending with the retraction of the anterior teeth, is a type of staging known as ***V staging*** **pattern** and typically applies only to the upper arch.

- The opposite of V staging pattern, in which the anterior teeth move anteriorly, followed by posterior teeth moving anteriorly, is known as **A staging pattern**.
- This pattern could be used in either arch to open previously closed extraction spaces or to attempt to mesialize an entire arch in a segmental fashion.
- This pattern will significantly lengthen the treatment time, as compared with X staging pattern staging, and has limited clinical applications.

- **M staging pattern** is solely used for bicuspid extraction treatment.
- In this staging pattern, movement starts by first closing the extraction spaces, followed by the alignment of anterior teeth, and finishing with molar movement.
- This three-dimensional simulation attempts to mimic maximum anchorage of the molars by showing no movement as the remainder of the arch changes.
- This does not clinically translate as shown in the three-dimensional simulation because forces are being applied to the molars as the arch perimeter changes with each successive aligner.
- In extraction treatment, which addresses molar anchorage and root parallelism, G6, the latest

Attachments

- One solution to aligner displacement is the proper design and placement of attachments.
- Attachments can be used for retention of the aligner as well as to enhance or facilitate specific tooth movements.



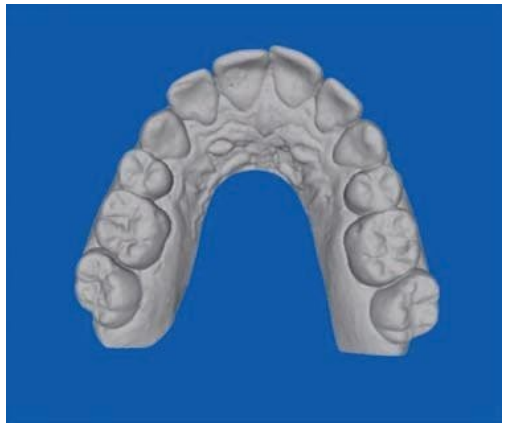
The evolution of attachments.

- The key is to provide a ledge for the aligner to grip that is perpendicular to the direction of displacement and of sufficient size to provide enough surface area to offset the force delivered.
- Another simple **rule of thumb** is to place the attachment far enough away from the gingival margin that the aligner will not spread or stretch and slip off the attachment.
- This is important because the aligners tend to relax over time; that is, exert less force, so the clinically observed side effect is that the gingival third tends to become less retentive.

- The approach them to evaluate the expected clinical response to various attachment designs and placements , based on the principles of biomechanics,is composed of three parts:

1. virtual modeling
2. in vitro testing
3. clinical evaluation of the resulting designs.

- **Virtual modeling** is first used to test a many possible solutions and identify those that produce the desired force system.
- These models may include changes in attachment shape as well as variations in the geometry of the aligner itself



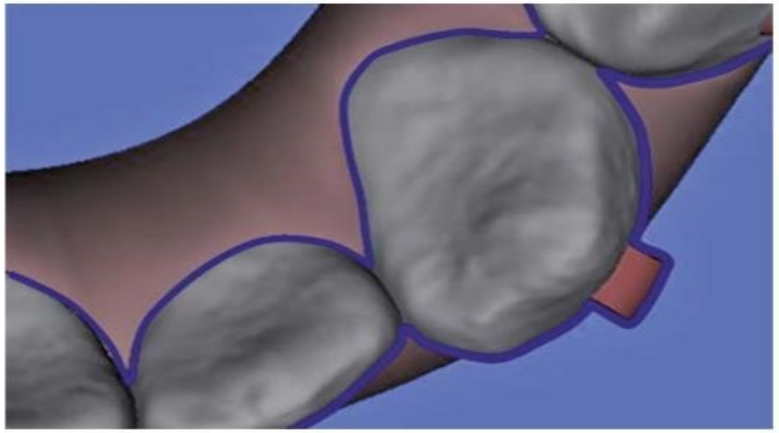
- After considering possible designs, they are then fabricated and the force systems are measured. Successful designs are then moved into **clinical testing.**
- At the time of this printing, Each optimized attachment is now custom designed for a specific movement on a specific tooth for an individual patient.

- Pre-activation is achieved by using an attachment template for attachment placement, which will alter only the optimized attachments that are slightly offset from the position of the attachment in the subsequent aligner that will be placed.
- This offset positions the active surface of the attachment to engage aligner material, thus eliminating a lag period of one to two aligners

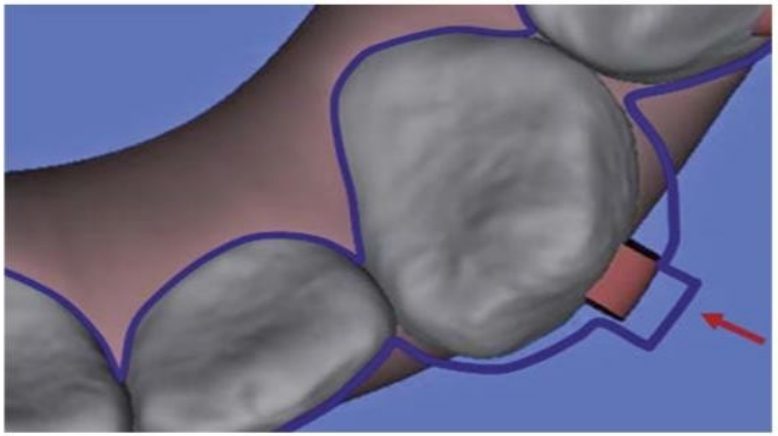
- Some optimized attachments will have excess space opposite the active surface to allow the tooth to move unimpeded in the correct direction.
- Although, clinically, this may give the appearance that the attachment is not fully seated in the aligner, this excess space is intentional by design.

- Another group of attachments are available to be placed by the orthodontist when modifying a virtual treatment plan - referred to as *manually placed* or *physician-prescribed* attachments.
- The **first of the manually placed attachments was the *ellipsoid* attachment**. This attachment is widely considered the least effective attachment because of its small size and lack of a defined active surface.
- All other attachments are variations of

- This rectangular attachment design was the primary attachment for any tooth movement that was considered moderate or difficult,
- The patient has difficulty inserting and removing the aligners, which is an inherent problem with rectangular attachments.



Aligner and rectangular attachment properly coupled.



Aligner and rectangular attachment improperly coupled.

- In order to facilitate greater ease of insertion and removal, as well as eliminate the all-or-none situation, the beveled attachment was developed by rotating a portion of the rectangular attachment virtu :h surfa

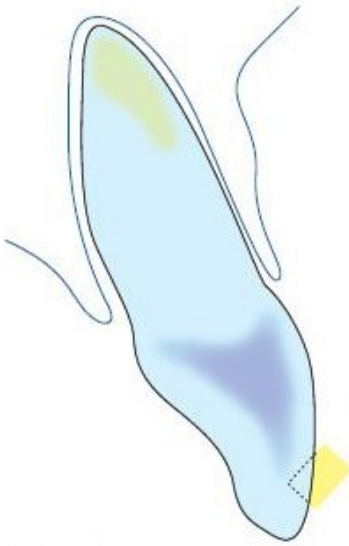
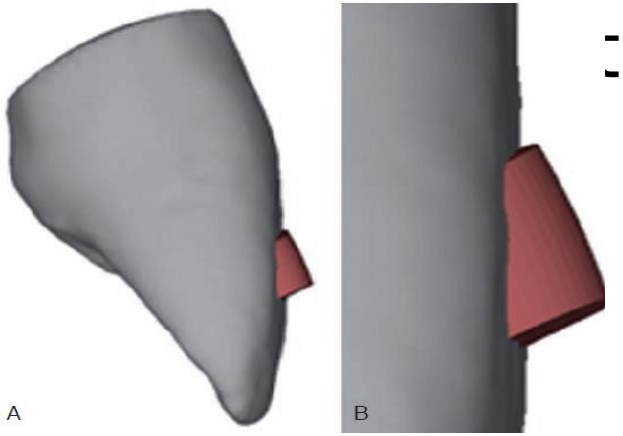


FIGURE 19-56 The beveled attachment.



Power ridges and pressure areas

- A net force of 40 g (base level force of an aligner after 48 hours) intended to move the tooth lingually would require a moment of 320 to 400 g-mm (M/F ratio 8-10) for bodily movement or greater than 400 gmm (F/M ratio less than 10) for lingual root movement

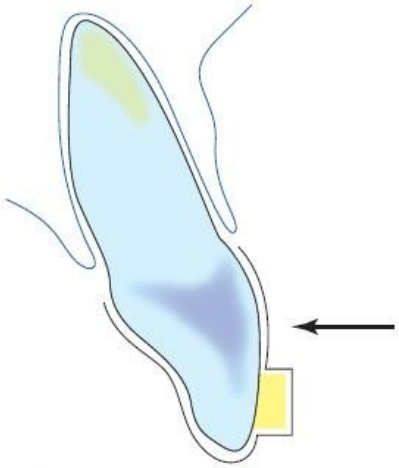


FIGURE 19-51 Force applied by aligner on facial surface.

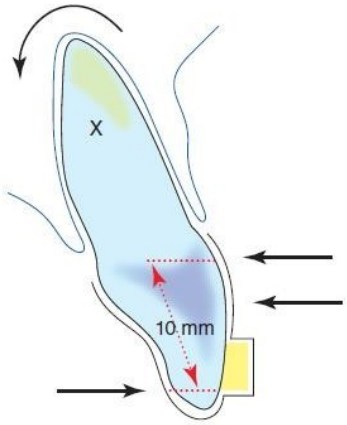


FIGURE 19-52 Force–moment diagram with attachment in incisal third of tooth.

- Improper attachment design or placement allows the delivery of only 280 g-mm moment in conjunction with 40 g force, resulting in controlled lingual crown tipping

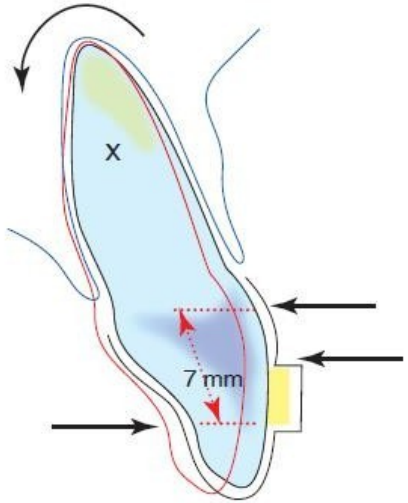


FIGURE 19-53 Force–moment diagram with attachment in middle third of tooth.

- An alternative to attachments that help facilitate torque control is the *power ridge.*
- Power ridges are engineered corrugations placed at specific locations to enhance the undercut near the gingival margin of teeth undergoing torquing movements.

- The ridges **function** in two ways

1. stiffen the gingival third of the aligner to make it more resilient.
2. provide additional force as close to the gingival margin as possible to increase the effective moment arm of the aligner.

- The **advantage** to power ridges is that attachments need not be placed or removed, and they are more aesthetically acceptable to the patient

Power ridges **disadvantages**.

1. they cannot be combined with any other attachment or SmartForce feature.
2. the gingival protrusion in the aligner has a dual purpose. Not only does it create a force near the gingival margin, but it also lifts the aligner away from the facial surface of the tooth until the aligner re- engages the tooth on the lingual surface of the incisal edge of the tooth.
3. create irritation of the buccal tissues attributable to the protrusion of the

- The latest additions to this family of SmartForce features are pressure areas on the lingual surface of maxillary and mandibular incisors and the lower cuspids to direct intrusive forces more closely down the long axis of the tooth when any of these teeth are intruding more than 0.5 mm.

Root Parallelism

- Another aspect of biomechanics, especially pertinent to extraction treatment, is to control tipping in order to achieve root parallelism.
- When a force is applied in an attempt to move a canine distally, the tooth will rotate about the centre of resistance.
- It would require a sufficient moment to oppose the tipping movement.

- This is a more problematic area because in a typical mesiodistal movement as in an extraction scenario, the aligner contacts the tooth on a surface that is parallel to the direction of force.
- The result is that there is little, if any, moment arm created without the use of substantial attachments

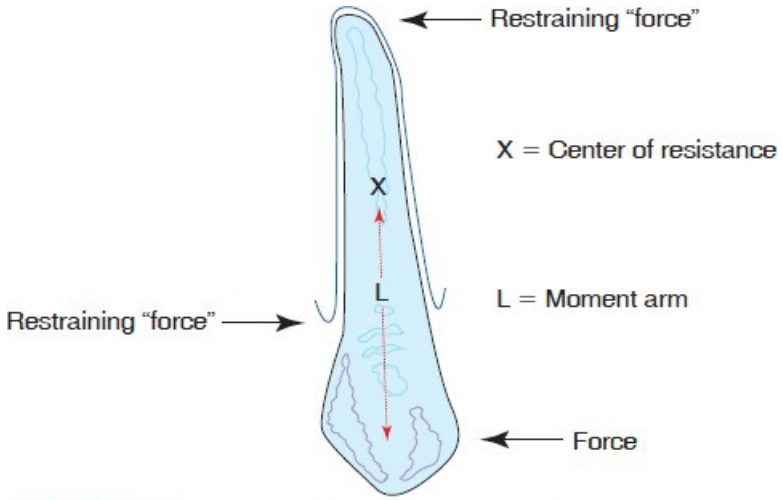


FIGURE 19-62 Force application against mesial of upper canine.

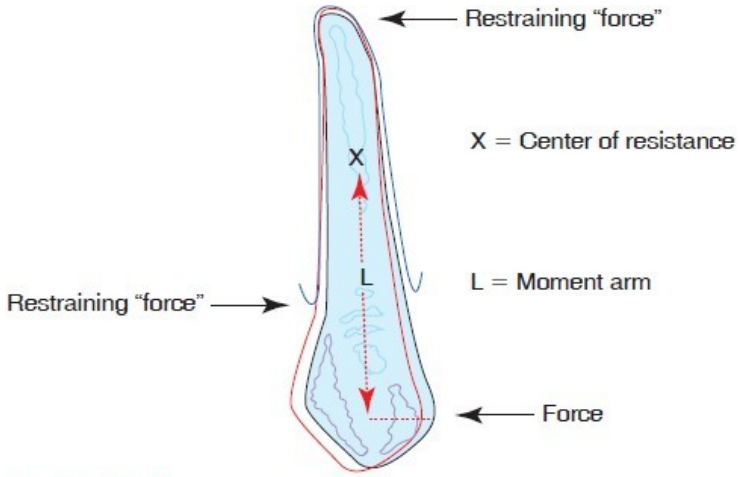


FIGURE 19-63 Effect of force application against mesial of upper canine.

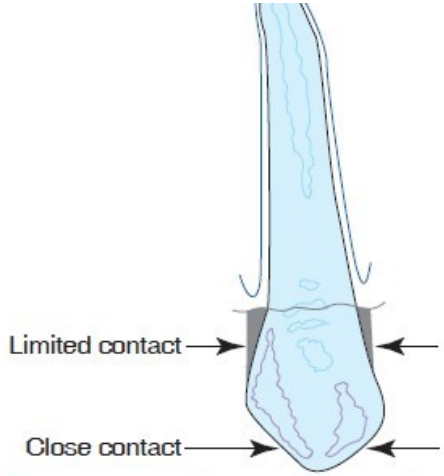


FIGURE 19-64 Diagram of aligner contact with upper canine.

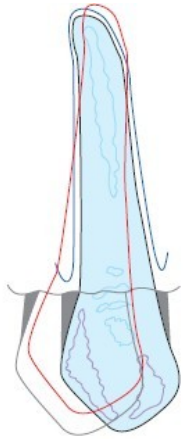


FIGURE 19-65 Displacement of aligner when force applied against mesial of upper canine.

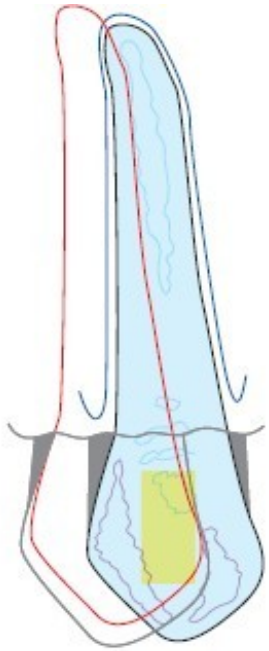


FIGURE 19-66 Controlled movement of upper canine with vertical attachment.

- An idea dating back to the late 1800swas to place an attachment on the gingival aspect of a bracket extending toward the center of resistance in an attempt to decrease the amount of tipping when teeth are moved mesiodistally.
- These gingival extensions are often described as power arms.
- Power arms have been added to the force system with Invisalign in an attempt to alter the force–moment system

- In theory, the addition of a power arm auxiliary accomplishes two things.
- First, it moves the application of force closer to the center of resistance.
- Second, it creates a secondary moment due to pressure against the distal of the aligner.
- Unfortunately, the clinical application is not as beneficial as with fixed appliances because molar root control is more difficult than canine root control.

- Align Technology has introduced engineered solutions in an attempt to mitigate the dumping in extraction cases and to help align the mesiodistal position of the roots of bicuspids, cuspids, and lateral and central incisors.
- These root control enhancements are SmartForce features, consisting of pairs of optimized attachments or one optimized attachment and a corresponding pressure area.
- Short clinical crowns on the maxillary and mandibular bicuspids will dictate the use

- Maxillary central incisors, maxillary cuspids, and mandibular cuspids use only the paired attachments where two facial attachments will create the couple designed to tip the roots.
- The upper lateral incisor multiplane feature uses an optimized attachment on the facial surface and a pressure area on the lingual surface.
- The root positions of lower incisors have been successfully maintained during single incisor extraction treatment without the use of engineered root control features and

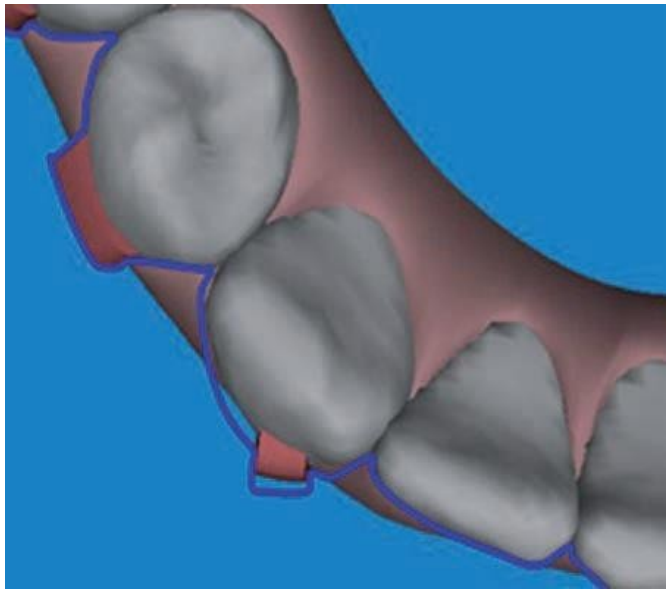
- Unfortunately, canines often remain upright during retraction into premolar spaces, whereas the clinical crowns of molars, especially maxillary molars, tend to tip mesially, which is frequently referred to as “dumping”
- Dumping occurs when the molars are being used as anchora
retraction.

- As the arch perimeter is reduced, closing extraction spaces, pressure is applied to the molar crowns in a mesial direction.
- This pressure is probably caused by the undesirable crown-root ratio combined with the large root surface area over which forces are distributed.
- G6, the latest release of SmartForce features, has antitipping attachments and pressure areas built into the molars to limit dumping of the clinical crowns in extraction cases.

Rotatio
ns

- Correcting rotations with aligners can be problematic.
- There are two primary reasons for this.
- The first is that aligners produce tooth movement by the plastic being slightly distorted and then elastically rebounding back to the predetermined shape and carrying the tooth with it.
- In the case of rotations, the aligner is incapable of being distorted in a manner that can produce significant rotational movement.

- Some have suggested that beveled attachments with the bevel turned 90 degrees (i.e., mesiodistally)would provide a surface to allow the aligner to rotate teeth.



- Even with a properly designed attachment, another problem with rotations is that the tooth root is not a cylinder, and because of dilacerations and root surface variations, there is no way the computer software can adequately estimate the true rotational long axis.
- In many cases what is thought of as a rotation of the tooth crown turns out to be bodily movement of the root surface; thus, estimating the proper rate of tooth movement becomes impossible.

- When this happens in fixed appliances, it simply takes longer for the tooth to rotate; when it happens with aligners, the aligner no longer fits the tooth.
- This results in lack of desired movement, but also, the aligner is now contacting different tooth surfaces than was intended.
- The result is either no movement or undesirable tooth movements.

- With many rotated teeth, there has typically been a need to use auxiliaries either before, during, or after aligner treatment in order to accomplish the rotational correction

- With the advent of the newer optimized attachments, the predictability of rotational movements has significantly improved.
- Optimized attachments are now available for all bicuspids and cuspids.
- The default for the bicuspids and cuspids is rotation correction greater than 5 degrees in either direction.
- Molars and incisors do not have engineered rotation attachments to date.

Extrusions

- One method previously used was to use the gingival beveled attachment to provide a longer surface area that can be elastically deformed and provide an extrusive force on the tooth.
- This model obviously had merit because Align Technology subsequently released an engineered solution to assist extrusion of maxillary and mandibular incisors and cuspids.
- The optimized attachments that assist extrusion are very similar to horizontal beveled attachments, beveled toward the

- The default that causes the attachment to be added to the virtual plan is extrusion of more than 0.50 mm down the long axis of the tooth.
- Relative extrusion, in which the crown of each incisor lingually reclines, may not trigger the placement of optimized extrusion attachments, even though the extrusion may be quite obvious.
- An additional SmartForce feature improves the tracking of anterior teeth extrusion when all four upper incisors are individually extruding more than 0.50 mm

- This additional feature alters the digital model to create a pressure area at the bases of the optimized attachment on the upper lateral incisors.
- This pressure area produces a higher force on the optimized attachment to keep the teeth fully engaged in the aligner.
- The addition of optimized attachments for extrusion and pressure areas on the upper lateral incisors has made Invisalign the preferred appliance for treatment of mild to moderate anterior open bite treatment.

- In particularly challenging situations, a button bonded to the tooth, together with an elastic, will assist with the extrusion.
- This method is infrequently used after the introduction of optimized attachments and can also be a very useful technique to finish treatment when only minor extrusion of a single tooth is required.

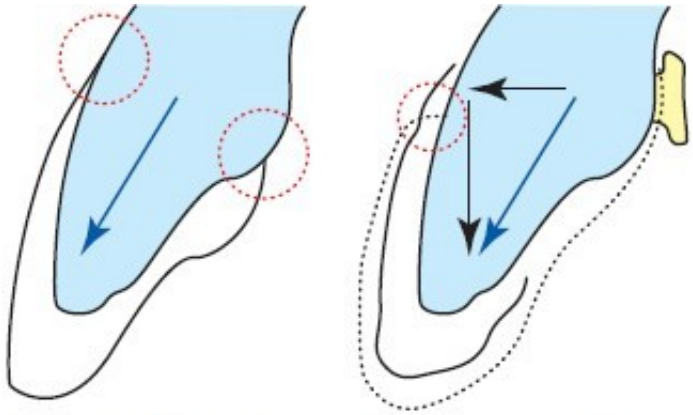


FIGURE 19-78 Extrusion auxiliary Diagram of extrusion mechanics with button and trimmed aligner.

Auxiliaries

- Other auxiliaries can be used to facilitate specific movements.
- Class II and Class III elastics are frequently needed just as they are with fixed appliances.
- One can either attach the elastics directly to the aligner or attach elastics to buttons bonded to the teeth.

- If the elastics are directly attached to the aligner, then attachments are generally required to prevent displacement of the aligner.
- Engineers at Align Technology have developed an elastic hook with the proprietary name “precision hooks and button cutouts” that are manufactured into the aligner. The orthodontist can place either of these options when modifying the ClinCheck using the ATTACH & CUTS interface.

- Mini-screws can also be used effectively with aligners in the same manner as they can with fixed appliances, either planned initially as part of the treatment or to help with movements that are not progressing as desired.
- They can be used with aligners alone or in combination with other auxiliaries to simplify the movements the aligners are required to accomplish.
- The two most common uses of mini-screws with aligners are for vertical and anteroposterior movements.

- One such example is the extrusion of an upper canine.
- Placing a miniscrew in the lower arch and then running a rubber band from a clear button near the gingival on the upper canine to the miniscrew guides the tooth into the corre

- Another vertical movement : intrusion of molars that have supererupted into an edentulous space.
- Place the miniscrews on the buccal and lingual aspects of an upper molar. The patient is asked to th
from one mini screw
aligner to the other

- Miniscrews can expedite Class II correction.
- The first example involves placing a Carriere Distalizer appliance (Henry Schein Orthodontics, Carlsbad, CA) in the upper arch along with a miniscrew in the lower arch in the molar or retromolar area.
- A Class II elastic is then worn 24 hours a day; generally, a Class I molar and canine correction can be expected in approximately 12 to 16 weeks.
- Once the sagittal molar and cuspid correction has been accomplished, then

A

- Another application of miniscrews with aligners is correcting an arch asymmetry by enhancing the distalization of one side.
- This correction can be accomplished by placing a miniscrew in the retromolar area, bonding buttons on the facial and lingual aspects of the upper first or second molar, and then connecting an elastic chain from the buttons to the miniscrew.
- If the intended movement is planned into the aligner treatment, then the mini screw provides the anchorage, and allows

- A Study done by Kravitz el al (2009)showed that:

1. The mean accuracy of tooth movement with Invisalign was 41%. The most accurate tooth movement was lingual constriction (47.1%). The least accurate tooth movement was extrusion (29.6%). The mandibular canine was the most difficult tooth to control.
2. Maxillary and mandibular canines achieved approximately one third of the predicted rotation. The accuracy of canine rotation was significantly lower than the rotation of all other teeth, with the exception of the maxillary lateral incisors. At rotational movements greater than

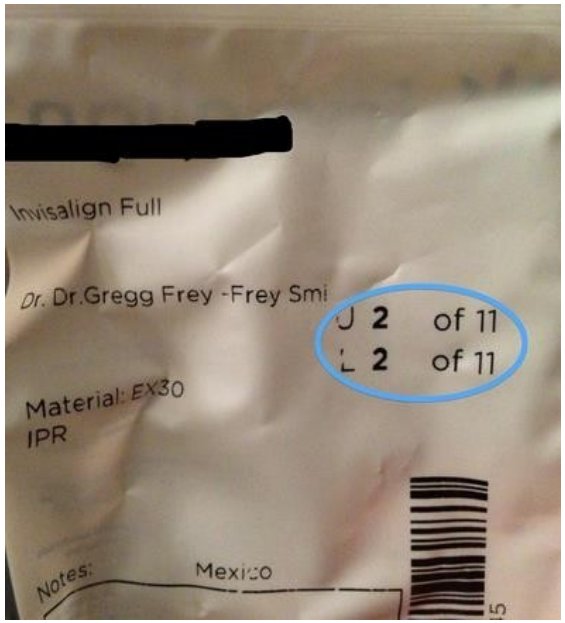
3.With the exception of canine rotation, no tooth was significantly less accurate in movement.

4.Lingual crown tip was significantly more accurate than labial crown tip, particularly for the maxilary incisors.

5.The severity of pretreatment overjet might influence the accuracy of anterior tooth movement with Invisalign.

Numbering of invisalign trays

- Normally invisalign is numbered low to high
- The Higher the Number the Closer to Finishing
- Numbers are laser inscribed on each aligner



Invisalign Teen

- It soon became apparent, however, that being able to treat the late mixed dentition with aligners provided certain benefits as well.
- The shortcomings to overcome were anticipating tooth eruption of one or more permanent teeth, being able to monitor patient compliance to discuss the progress (or lack thereof) with parents, proper control of torque without the need for attachments when crowns were not yet fully exposed, and, finally, avoiding practice management issues over lost aligners.

- Eruption tabs are used to prevent supereruption of unerupted second molars

- Tooth forms of approximate anticipated crown size are used to both create and hold room and to guide eruption of actively erupting second premolars and canines, planning for refinement aligners with proper fit once the teeth are adequately erupted to capture properly the crowns in the impression.
- Wear indicators (Compliance indicators) are placed on the facial surfaces of the first molars.
- Two different types of chemical indicators are available, that turn from dark blue to

- These indicators are designed so that creative teenagers cannot realistically figure out a method to have both indicators change without actually wearing the aligners

- All SmartForce enhancements, including optimized attachments, pressure points, and pressure areas were developed for the Invisalign Teen product and are a routine part of the feature set.
- The practice management part is actually quite easy.
- Align Technology charges a premium and provides free replacements for lost aligners.
- In reality, the patient prepays for the privilege of having them replaced if lost.

- Understanding when and where to anticipate the use of aligners in combination with other techniques or auxiliaries is critical to both getting satisfactory results and satisfying patients.
- Several variables combine to produce either acceptable desired results or unacceptable undesired tooth movements.
- The first and most important variable is duration of wear.
- Aligners are not retainers and must be consistently worn for approximately 22 hours of a 24-hour period, essentially acting similar to fixed appliances

- The next most important variables are clinical crown length and shape.
- The longer the clinical crown and the greater the natural undercuts to facilitate aligner retention, the more likely that the desired movement will take place, because there is a greater amount of surface area for the aligner to contact.
- Patients with very short clinical crowns are not good candidates to attempt some movements with Invisalign such as root alignment with premolar extraction treatment.
- Single lower central incisor extraction tends to be successful because of the length of the clinical crowns of the lower incisors relative to the forces applied.

- Closing anterior spaces, especially with protrusive incisors that require some intrusion, is extremely predictable and requires no attachments.
- Closing minor anterior open bites is predictable because one secondary effect of aligner wear is the vertical control of dentoalveolar eruption of the posterior teeth.
- In growing patients this is particularly poignant. Because aligners tend to limit posterior tooth eruption, when opening a deep bite, special consideration should be given to the virtual setup

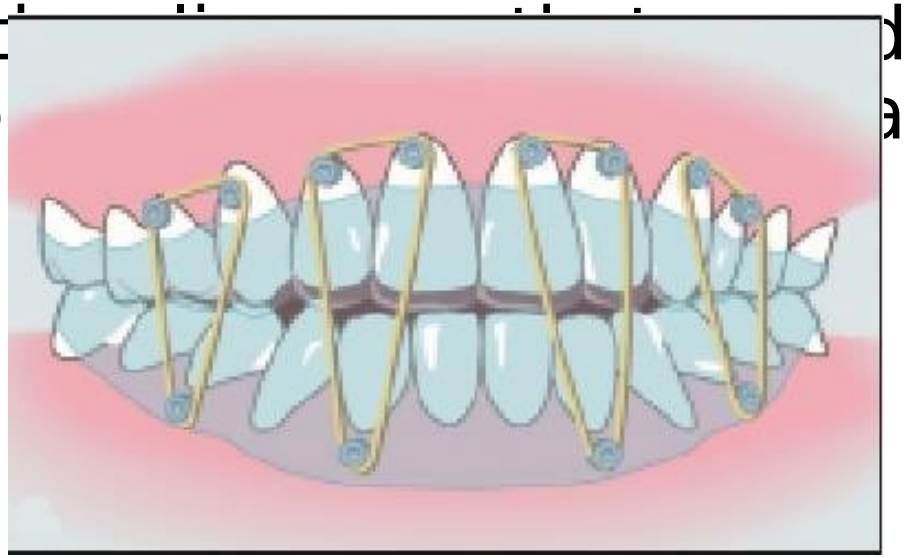
- If the curve of Spee is deep, then intruding lower second molars and lower incisors (using the aligner as if it were a reverse curve of Spee archwire) leaves only a small amount of extrusion of the premolars and first molars.
- Along with the reverse curve of Spee effect, heavy posterior occlusal contacts can be virtually created to compensate for the side effect of molars and bicuspids not being able to extrude easily.

- Leveling the curve of Spee has now been made significantly easier with the addition of the virtual bite plane being added to the lingual aspect of the upper incisors. This addition was part of the G5 release in 2014 to address deep bite treatment.
- Opening the bite is accomplished by creating virtual collisions between the upper and lower molars when modifying the ClinCheck.

COW-CATCH ALIGNERS

- Clear aligners with intermaxillary elastics
- To fabricate a clear aligner for correcting an open bite, an impression is taken and a working cast produced. The teeth on this cast are ideally set-up (extruded) before a 1-mm plastic sheet (Duran, Scheu-Dental, Iserlohn, Germany) is formed with either a pressure- molding machine (Biostar, Scheu-Dental, Iserlohn, Germany) or a vacuum machine (Raintree Essix, Sarasota, Florida,USA).

- The teeth to be extruded are supplied with buttons and connected to the opposite arch with elastics where buttons were attached to the aligner.
- When the expected extrusion is achieved, the respective teeth will contact the inner surface of t dditional extrusion o afe appliance.



Periodontal Considerations

- There is a body of evidence growing that orthodontic treatment with aligners has less detrimental periodontal impact than that of fixed appliances.
- Miethke and Vogt and Miethke and Brauner compared the periodontal health of patients who underwent treatment with aligners to that of patients who underwent treatment with both labial fixed appliances and with lingual fixed appliances and found that the periodontal risk was no greater than with labial appliances and was lower than that of lingual fixed appliances.

- Boyd found that periodontal health could actually improve during the course of treatment with Invisalign.
- He attributed this to the patient’s ability to remove the appliances and spend more time brushing and flossing their teeth and the aligner’s ability to maintain an invisible appearance to the appliances.

CONCLUSION

- Not all malocclusions are amenable to treatment solely with the Invisalign system.
- Treatment of many malocclusions with proper tip, torque, arch form, and aesthetic crown inclination is possible to achieve with aligners.
- Besides the obvious aesthetic improvement over fixed appliances, there may also be periodontal health benefits associated with Invisalign treatment.

- Understanding both the process of aligner manufacturing along with the biomechanics of tooth movement with aligners and applying that knowledge to treatment planning and clinical execution should enable the clinician to design a treatment plan with aligners alone or in combination with fixed appliances to make both simple and complex treatment predictable and routine.